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Warming Up To Solar Cooking- A Comparative Study On Motivations And The Adoption Of Institutional Solar Cookers In Developing Countries

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Abstract

In many developing countries people rely on firewood as a primary energy source which has negative health and environmental consequences. Solar cooking offers a solution to overcome those problems. The promotion of solar cookers has become very popular over the years and a wide range of organizations promote different types of solar cookers around the world. However, it is not clear how many of those cooking systems are still in use. The literature on solar cookers is very limited and has focused mainly on household solar cookers, while solar cookers for institutional applications have been ignored. This study contributes to this debate by comparing application levels of an institutional type of solar cooker (Scheffler reflectors) in different developing countries. Preliminary results show that different types of motivational factors play an important role for adopting this type of solar cooker. Motivational aspects were divided into economic, health and environmental factors. The analysis shows that in nine out of 24 cases Scheffler reflectors were in use and that in all these nine cases motivational factors were present. Furthermore, we can see that institutions mainly emphasize economic and environmental motivational aspects, while positive health effects were mentioned in just two cases. In addition, three identified cultural variables were present in all nine positive adoption cases. The study shows that the more similar the solar kitchen is to the conventional way of cooking, the more successful it tends to be. However, those cultural variables alone do not lead to the continuous use of solar cookers; they have to be combined with the earlier-mentioned motivational aspects.

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Keywords: Solar cooking; Rogers' Innovation-Decision Process; Scheffler reflectors

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1. Introduction

In many developing countries people rely on firewood as a primary energy source. Firewood is particularly used for cooking on so-called "three stone fires", which are inefficient and produce high levels of smoke. The smoke can lead to respiratory diseases, especially among women who are often in charge of the cooking process. Furthermore, the use of firewood is unsustainable for the environment. Population growth and consequently the increased use of firewood lead to deforestation in many developing countries. Solar cooking could solve this problem. Solar cookers are regarded as a clean cooking technology because they do not produce smoke as the conventional use of firewood for cooking. Simultaneously, they reduce the unsustainable use of firewood in developing countries. The promotion of solar cookers has become very popular over the years and a wide range of organizations promote different types of solar cookers around the world. However, it is not clear how many of those cooking systems are still in use. The literature on the use of solar cookers is very limited and different articles have mainly focused on household solar cookers while solar cookers for institutional applications (such as schools, hospitals, and religious centers) have been ignored. Furthermore, in an academic context, research on the social aspects of solar cookers has not found primary concern. Most research has been related to technical improvements of solar cookers (see: [1], [2, 3], [4], [5], [6]) while the social context and particularly issues related to successful adoption of solar cookers have been widely ignored.
This study contributes to this debate by comparing levels of application of an institutional type of solar cooker (Scheffler reflectors) in different developing countries. The data is based on extensive fieldwork in four countries where Scheffler reflectors were implemented. Interviews were conducted with institutions using and not using Scheffler reflectors in India, Burkina Faso, Botswana and South Africa, to find out which factors explain the continuous use of those systems.
The paper will start by presenting the theoretical framework and methodology applied in this study followed by an analysis and discussion of the data and concluding remarks and outlook for further studies.

2. Theory

The adoption of solar cookers will be analysed by testing a theoretical framework which I developed in my PhD study based on a literature review on relevant variables for solar cooking and Rogers' Innovation-Decision Process[†]. In this theoretical model factors influencing the use of solar cookers can be divided into six categories including (1) economic, (2) cultural, (3) social, (4) political, (5) technical and (6) environmental factors. In reviewing the literature, a total of 19 variables could be identified. The list of variables is presented in Table 1. We can see that the list of variables is rather complex. By applying Rogers' Innovation-Decision model this complex list was reduced to nine variables assumed to be relevant for solar cooking. Rogers describes the decision process of an individual adopting or rejecting an innovation as a five stage process. The stages include (1) knowledge, (2) persuasion, (3) decision, (4) implementation and (5) confirmation [19].

[†] This paper presents a small part of my dissertation entitled "Sunrise or sunset? – A comparative study on the successful adoption of solar cookers in the developing world". A full description of the literature review, the theoretical framework and the derivation of the relevant variables can be found there in chapter 3.

Table 1Variables relevant for solar cooking

Economic	Cultural	Social	Political	Technical	Environmental
Affordability [7]	Food characteristics [8]	Motivation [9] [10]	Financing schemes [11]	Satisfying performance [12]	Availability & price of alternative fuels [13]
Local production can create employment opportunities [14]	Traditional cooking habits [12]	Existing power & gender relations [7]	Dissemination strategies [14]	Easiness to use [15]	Availability of suitable place [8]
	Schedule of daily routine [16]	Use of solar cookers by its disseminators [16]		User-friendliness [17]	Levels of solar radiation [18]
		Supplier characteristics [16]		Sensitivity to reparation [15]	Levels of infrastructure [18]

Furthermore, he distinguishes between two forms of discontinuance of an innovation, which are replacement and disenchantment. Replacement occurs when an individual (in our case institution) finds another idea/innovation to adopt, which is considered to be better than the old one. Disenchantment means that an individual rejects an innovation because he/she is not satisfied with its performance. In this case the innovation might not have the desired relative advantage over other ideas or it is inappropriate for the individual. Another reason for discontinuance can also be that the innovation was misused and does not bring the desired advantages anymore.

The review on the relevant variables shows that technical issues were particularly relevant to the discontinuance of solar cookers [8, 15]. This goes along with the concept of disenchantment as reason for discontinuance. In the case of disenchantment discontinuance, Rogers argues that the use of an innovation is stopped because of dissatisfaction with the performance of the system. In this case the innovation turns out as inappropriate without leading to the desired relative advantage. This brings us back to the persuasion stage in Rogers' model, which decides if an individual becomes interested in an innovation. Rogers identified five main factors as having an impact on the outcome of the persuasion stage, and which influence whether an individual develops interest in an innovation. These factors comprise: (1) relative advantage, (2) complexity, (3) compatibility, (4) trialbility and (5) observability. In the case of discontinuance, our initial situation is that an individual earlier decided to adopt a solar cooking system but the desired outcome did not take place. In this case, the solar cooker does not show the relative advantage as assumed by its user. In order to find out which factors lead to the dissatisfactory performance, we have to look more closely on the key aspects that drive this relative advantage. In the case of solar cookers these are the complexity and compatibility of the cooker. The two other concepts including trialability and observability can be ignored at that point because the institutions already decided to make use of the solar cooking system. This directs our focus to two concepts: complexity and compatibility. For these two concepts the following variables presented in Table 2 are seen as relevant:

Table 2 Relevant variables for Rogers` concepts

Complexity	Compatibility	Confirmation stage
(1) Ease of use	(5) Cooking habits	(8) Supplier characteristics
(2) User-friendliness	(6) Food characteristics	
(3) Satisfactory performance	(7) Daily schedule of routine	
(4) Sensitivity to reparation		

This means we have seven variables relevant for the use of solar cookers. In addition to these seven variables derived from the persuasion stage, we have to consider the relevant variables of the confirmation stage. According to Rogers [19], an individual will seek reinforcement for his/her decision after adopting or rejecting an innovation. In this stage, (8) supplier characteristics can have an impact on the previous decision of an institution. For our case this means we need to find out how far supplier characteristics such as for example, maintenance service, contribute to the use/rejection of solar cookers. Thus we add "supplier characteristics" to our final list of variables.

Besides the relevant variables included in compatibility, complexity and supplier characteristics (9) motivation is an important variable influencing the final adoption or discontinuance of solar cookers. Motivation is not included in Rogers' original model but other scholars have discussed the role of motivation as an important precursor to interest (persuasion stage) [9] [10]. Thus, using Rogers' Innovation-Decision Process as a theoretical framework, the original 19 variables can be reduced to nine core variables: (1) user-friendliness, (2) easiness to use (3) satisfying performance, (4) sensitivity to reparation, (5) cooking habits, (6) food characteristics, (7) schedule of daily routine, (8) supplier characteristics and (9) motivation.

The nine core variables are compared across 24 cases included in this study. Those cases present institutions, which successfully adopted or rejected solar cookers. The institutions included in this study use either direct heat for cooking or they generate steam with solar energy. Both make use of the same technology (Scheffler reflectors) but for those two different applications. Solar steam kitchens are used among larger institutions where food is prepared for a large number of people (> 1500 people). Direct solar kitchens prepare food for a much smaller number of people (> 50 people).

3. Methodology

The nine variables were operationalized in the form of interview questions. For the analysis QCA (Qualitative Comparative Analysis) was applied. QCA is an approach developed by Charles Ragin in the 1980s. It combines the advantages of case and variable oriented comparative methods and allows for conjunctural causation. It is a very useful tool for research when we assume that a certain outcome (Y) is produced by a combination of conditions[‡]. In our case we assume that the nine conditions included from the theoretical framework will have an impact on the use of solar cookers. In total the study includes 24

[‡] In the QCA language "variables" are called "conditions". The term is applied in the following.

cases from four countries (India, Burkina Faso, Botswana and South Africa)[§]. The levels of use of a particular institutional solar cooker were compared in those countries. The total number of cases is limited due to cost and time limitations and does not allow for any statistical generalizations. However, QCA presents an appropriate tool for the analysis of intermediate number of cases as in this study. Furthermore, QCA is a very case intensive research method, which requires in-depth knowledge for the analysis. In order to understand the QCA analysis applied in this study, I need to explain some of the terminology used within QCA. In general QCA is based on the laws of Boolean algebra. In this study a crisp set QCA was applied, which means that the data is coded as [1] for presence of successful adoption and [0] for absence of successful adoption. This means that based on the statements of the interviews each of the nine conditions was calibrated as either present [1] or absent [0] across the 24 cases. A first raw data table showed that in all 24 cases it was reported that the system is sensitive to reparation. Furthermore, in 22 out of 24 cases the system was described as easy to use and in 20 out of 24 cases the system was considered to be user-friendly. One basic rule for QCA is that conditions included in the analysis should vary. The three variables that were constant (or showed little variation) across the data set were therefore excluded. This reduces the complexity of the analysis because by reducing the number of conditions from nine to six, across the 24 cases; i.e., we reduce the theoretically logically possible space. The formula for Boolean algebra is 2^k. The letter k indicated the number of conditions and two the dichotomous memberships [1] presence and [0] absence [20]. By having nine conditions we have 512 theoretically/logically possible combinations, by reducing them to six we are left with 64 theoretically/logically possible combinations. Table 3 explains the abbreviations and meanings of the original conditions for the QCA analysis.

Table 3 Abbreviations and original names of conditions

Abbreviation	Condition
Foodchar	High conformance with local food characteristics (1) Not high conformance with local food characteristics (0)
Cookhab	High conformance with local cooking habits(1) Not high conformance with local cooking habits (0)
Schedule	High conformance with schedule of daily routine (1) Not high conformance with schedule of daily routine (0)
Perform	High level of performance (1) Not high level of performance (0)
Supplier	Positive supplier characteristics (1) Not positive supplier characteristics (0)
Motivat	High levels of motivations (1) Not high levels of motivations (0)

After calibrating the conditions, we are left with the raw data table presented in Table 4. The raw data table shows the calibrations of each condition in each of the 24 cases. By taking a look at the positive outcome cases in the raw data table, we can see that motivation is always present when the outcome is present. This means that it seems to be a necessary condition. However, we can also see that motivation is in one case present (Burkina Faso 2) where the outcome is not present. This means that motivation is not a sufficient condition. Motivation presents a macro-variable and in order to investigate more the role of "high levels of motivation" as necessary condition, we split the macro variable "high levels of motivation" into its three dimensions (I) economic, (II) health, and (III) environmental motivation. Economic motivation captures savings of energy expenditures or the possibility of generating an income

§ A high number of cases was collected from India (16 cases included in the data set). This is due to the reason that Scheffler reflectors are much more implemented in India than on the African continent. However, it was possible to trace back a total of eight cases on the African continent.

by using solar cookers. A health type of motivation states that an institution is particularly interested in solar cooking because of its health benefits (e.g., the absence of smoke, which results when cooking with fire). Last but not least the environmental type of motivation captures whether an institution is interested in protecting the environment and sees the potential of solar cooking for saving the environment. The different motivational aspects were coded as [1] present in cases where the current leadership and cooks showed high levels of motivation. In cases where it was reported that the leadership changed over the years from a "motivated " to a less "motivated" leadership with regards to solar cooking, the conditions were coded as [0] absent. However, by splitting motivation we have to keep in mind that we will also increase the level of limited diversity because one previous measured condition "high levels of motivation" suddenly counts as three conditions. This means that we increase the level of theoretically/logically possible configurations, since we do not increase the empirical number of cases.

Table 4 Final dichotomized table of relevant variables

Case ID	Foodchar	Cookhab	Schedule	Perform	Supplier	Motivat	Adoption
India 1	0	0	0	0	1	0	0
India 2	1	1	1	1	1	1	1
India 3	1	1	1	1	1	1	1
India 4	1	1	1	1	0	0	0
India 5	1	1	1	0	1	1	1
India 6	0	1	0	1	0	0	0
India 7	1	1	1	0	1	1	1
India 8	0	0	0	1	1	0	0
India 9	1	1	1	1	0	0	0
India 10	1	1	1	1	0	1	1
India 11	1	1	0	0	0	0	0
India 12	1	0	0	0	0	0	0
India 13	1	1	1	0	1	1	1
India 14	1	1	1	1	1	1	1
India 15	1	1	1	1	1	1	1
India 16	1	1	1	1	1	1	1
South Africa 1	0	0	0	0	1	0	0
Botswana 1	1	1	0	0	0	0	0
Botswana 2	1	1	0	0	0	0	0
Burkina Faso 1	0	0	1	1	0	0	0
Burkina Faso 2	1	0	0	0	1	1	0
Burkina Faso 3	0	1	0	0	0	0	0
Burkina Faso 4	0	0	1	1	1	0	0
Burkina Faso 5	0	1	0	0	0	0	0

After splitting motivation into its three dimensions, we can run a test of necessity with fsQCA to find out which of the dimensions are the necessary conditions that produce a positive outcome (successful use of solar cookers). The test of necessity is presented in Table 5. We can see that environmental and economic motivation show high consistency levels while health-related motivational aspects are very low (0.22) because they were only mentioned as relevant in two out of nine positive adoption cases. However, economic and environmental motivations show the same levels of consistency (1.0).

Table 5 Necessary conditions analysis, including three dimensions of motivation

Conditions tested	Consistency	Coverage
Economic	1.00	1.00
Health	0.22	0.67
Environ	1.00	0.90

In a next step of the analysis we can design a truth table to test further the role of motivation on the use of solar cookers. A truth table provides us with an overview of all logically possible configurations of conditions and shows us which of our cases entail which of those configurations. Furthermore, the truth table shows us how cases cluster together [21]. We can design a truth table, by using the Crisp Truth table Algorithm developed by Ragin in fsQCA. In our case I ran a truth table with TOSMANA software. By running the truth table algorithm, we can organize the 24 cases into 12 out of 64 logically-possible configurations. This implies that there are 52 logical remainders (possible logical configurations without empirical evidence)[**]. The truth table is presented in Table 6.

Table 6 Truth table

Config.	Foodchar	Cookhab	Schedule	Perform	Supplier	Motivat	Outcome	Case ID
1	0	0	0	0	1	0	0	India 1,South Africa 1
2	1	1	1	1	1	1	1	India 2, India 3, India 6, India 12, India 13
3	1	1	1	1	0	0	0	India 11, India 14
4	1	1	1	0	1	1	1	India 10, India 15, India 16
5	0	1	0	1	0	0	0	India 4
6	0	0	0	1	1	0	0	India 5
7	1	1	1	1	0	1	1	India 7
8	1	1	0	0	0	0	0	India 8,Botswana 1 , Botswana 2
9	1	0	0	0	0	0	0	India 9
10	1	0	0	0	1	1	0	Burkina Faso 2
11	0	1	0	0	0	0	0	Burkina Faso 3, Burkina Faso 5
12	0	0	1	1	1	0	0	Burkina Faso 1, Burkina Faso 2

4. Discussion

4.1. The role of cultural variables

By taking a closer look at the truth table we can see that in all nine positive adoption cases three cultural conditions were calibrated as [1] present (Configurations 2,4 and 7). Those conditions are [1] food characteristics, [1] cooking habits and [1] schedule of daily routine. Eight out of nine cases, which show the presence of those three conditions are larger institutions making use of solar energy for steam cooking. These are India 3, India 6, India 7, India 10, India 12, India 13, India 15 and India 16. This is one of the advantages of using truth tables. Berg Schlosser et al. [21:15] state that with the help of a truth table "the researcher will be able to bring to light similarities between cases that may, at first sight, seem quite different. " In our case we can see that the cultural conditions are rather constant among those cases. To analyse configurations 2, 4 and 7, in-depth case knowledge becomes relevant. We can see that those three configurations show the same configurational combinations of the cultural conditions but do differ in terms of "high level of performance" (PERFORM) and "positive supplier characteristics" (SUPPLIER). The major explanation for why those cultural conditions are rather constant in those cases is that the use of solar steam cooking does not lead to any changes in the cultural cooking conditions. Those institutions have a solar cooking system installed on the roof of their kitchens with which they can generate steam. This system is often installed as an additional component to a previous installed diesel boiler and reduces the diesel consumption during sunny days. Interviews with the cooks at those larger institutions showed that the cooking situation does not change as such. The cooks are not directly involved in the steam generation process. Workers are normally employed for the maintenance and the

[**] This is still a high number of logical remainders. In the dissertation this problem was tackled in a further analysis by applying a two- step QCA approach for the final analysis.

operation of the steam system. Those workers are trained how to maintain the system (e.g., cleaning of the mirrors, oiling of the tracking system) and they also keep track of the hourly steam pressure. When the solar steam kitchen reaches the appropriate level of steam pressure, the workers switch to the steam produced by the solar system for food preparation.
The cooks are normally excluded from this process. They do their work in the kitchen and are used to steam cooking from the time when they relied entirely on the diesel boilers. This means that the cooks prepare food in exactly the same way as they did before the instalment of the solar steam system and that there is no change in the cooking situation. In relation to our conditions, this means that the food prepared with a solar steam system shows high levels of conformance with the predominant food characteristics (FOODCHAR.), high conformance with traditional cooking habits (COOKHAB.) and high conformance with the conventional schedule of daily routine (SCHEDULE). Figure 1 shows two cooks preparing steamed rice at one of the larger institutions in India included in this study, where the solar kitchen was successfully in use. Here we can see that the cooks are not in direct contact with the solar steam kitchen on the roof of the building but prepare the food in the conventional way of steam cooking.

Figure 1. (a,b) Steam cooking

The fact that the cooking situation does not change for the cooks using solar steam kitchens could explain why solar steam kitchens show high adoption levels in the data set. In comparison, institutions using solar kitchens for direct heat cooking show differences in the way food is prepared. Here the cooks have to get used to a different way of cooking.

4.2. The role of motivation

Preliminary results show that different types of motivational factors play an important role for adopting this type of solar cooker. The analysis shows that in nine out of 24 cases, Scheffler reflectors were in use and that in all these nine cases motivational factors were present. The important role of motivational factors for the use of solar cookers is consistent with an earlier study conducted by Sutter [22] which included some of the solar kitchens which were also part of this study. Sutter reports that the personal motivation of the decision maker of an institution was seen to be significant when a small problem with a solar cooker occurred and had to be fixed. In places where the personal motivation was low, the smallest problem with the solar cooker led to its discontinuance. However, this study examined the motivation factor a bit closer than the evaluation by Sutter, by dividing motivation in three dimensions (environmental, economic and health) to investigate deeper the type of motivation present, leading to the successful use of solar cookers.

We could see that institutions mainly emphasize economic and environmental motivational aspects, while positive health effects were just mentioned in two cases as a motivational reason. In addition, most of the positive adoption cases include large solar steam kitchens, which do not make use of firewood for cooking. This means that the reduction of smoke production is not an issue among those institutions, since they already cooked with steam before. It is just that the source of energy for steam generation changes by using the solar kitchens. This explains why health motivational aspects were calibrated as [0] absent in many cases. Furthermore, this also indicates that solar kitchens find another user-group as originally intended by the literature. In the introduction it was argued that solar cookers are often promoted for “poor” households which make use of firewood for cooking. However, this study shows that solar kitchens can be successfully applied in a larger institutional dimension without having the health related benefit. This means that motivation can be regarded as a relevant variable influencing the continuous use of Scheffler reflectors. However, the question remains how far motivation alone can explain the use of solar cookers and whether there are not other variables which have an impact on the adoption of solar cookers. Section 4.1 shows that three cultural factors seem to play an important role for the continuous use of solar kitchens. We could see that the more similar the solar kitchen is to the conventional way of cooking, the more successful it tends to be. However, those cultural factors alone do not lead to the continuous use of solar cookers; they have to be combined with the earlier-mentioned motivational aspects.

5. Conclusion

The study investigated the use of solar kitchens among public institutions with cases from four different countries, to find the determining factors that make institutions adopt solar cookers. The preliminary results of the study show that solar kitchens are successfully adopted among larger public institutions in India which use solar energy for steam cooking. We could see that of six earlier-identified relevant conditions, motivational factors and the three cultural conditions (food characteristics, cooking habits and schedule of daily routine) were of particular significance. Motivational factors were split into its three dimensions: economic, environmental and health motivational factors and the study showed that the presence of economic and environmental motivational factors was relevant for the continuous use of solar cookers. Eight out of nine positive adoption cases include larger solar steam kitchens. We could see that in those cases the cooks did not report any changes in the way food was prepared due to the use of solar energy. The cooks prepare food in the same way as before, only the energy source for generating steam is solar instead of diesel. However, the question remains whether solar cooking is also adopted by smaller institutions that make use of direct solar kitchens where it can be less controlled for those factors. This paper presented a first part of the final analysis of my comparative study on solar cooking in the developing world. Furthermore, a first step of the QCA analysis was undertaken and it will be part of the further analysis to investigate the use of smaller direct solar kitchens. However, an interesting preliminary finding is that the presence of motivational factors - in terms of economic savings and preserving the environment - among public institutions seem to be very relevant prerequisite for the use of solar cookers.

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